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Preemptive Bribery with Incomplete Information

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Abstract

This paper studies bribery between a firm and a supervisor who monitors the firm for compliance. Bribery occurs preemptively, that is before the supervisor exerts costly effort to discover the firm's level of non-compliance and collect evidence for successful prosecution. In contrast to previous papers, preemptive bribery is modeled as a Bayesian signaling game because the supervisor is uninformed about the firm's level of non-compliance. We show that when the collection of evidence is independent of the supervsior's knowledge of the firm's level of non-compliance, some (possibly all) firms always engage in preemptive bribery. However, if knowledge of the firm's level of non-compliance has implications for the supervisor's ability to collect evidence and prosecute, preemptive bribery can be completely eliminated. Results which apply to preemptive bribery under complete information do not apply here.

1 Introduction

It is well recognized that corruption and bribery undermine enforcement efforts in various regulatory settings. In particular, collusion between the supervisor who is in charge of enforcement and the agent or firm that is being regulated, leads to dilution of enforcement. While there is a sizeable literature on this, the focus is mostly on ex post collusion, which takes place after the supervisor has collected evidence regarding the firm's non-compliance (Polinksy and Shavell 2000). Indeed, Mookherjee and Png (1995) provide a detailed analysis of the conditions under which ex post bribery will occur and how it must be deterred. However, bribery can occur even before the supervisor has carried out inspections. In other words, there is scope for preemptive bribery where the supervisor accepts a bribe in order not to carry out any inspection (Bac 1998, Bag 1997, and Samuel 2009).

Preemptive bribery differs from ex post bribery in two important aspects, which complicates the analysis of its incidence and deterrence. On the one hand preemptive bribery is more likely to occur because the coalition of the firm and the supervisor saves on the inspection costs by engaging in preemptive bribery and there is no risk of the evidence "leaking" and being used in the future to prosecute the firm and the supervisor. On the other hand, while ex-post bribery occurs after the firm's non-compliance is observed by the supervisor, preemptive bribery takes place with a relatively uninformed supervisor. Arguably, the presence of asymmetric information may be sufficient to disrupt the preemptive bargaining process, thereby, preventing preemptive bribery from occurring (as Ryvkin and Serra 2012 have shown in a different context).

The objective in this paper is to show that the incentives for collusion and the capacity to deter it depend critically on when bribery takes place, that is whether preemptively or ex pot, and the (related) informational environment in which it occurs. To achieve this, we study bribery in a regulatory setting where a supervisor must exert costly effort to find evidence regarding a firm's pollution level, and conditional on successfully observing the firm's pollution level (or more broadly, its level of non-compliance with regulations), the supervisor is required to report this compliance level to the regulator who imposes a fine on the firm based on this report. We allow bribery to occur both preemptively under incomplete information and ex-post under complete information.

Our study highlights the role of information as an important difference between preemptive and ex-post bribery and adds to the existing literature that examines whether a principal can deter collusion by introducing imperfect information. Kofman and Lawarree (1996), for example, show that a principal may hire two supervisors to inspect the same firm sequentially. They show that if each supervsior does not know for certain whether she is the first or the second to inspect the firm, collusion is deterred.[1] Similarly, Lambsdorff (2007), using cross-country data, finds that uncertainty regarding the size of the bribe can reduce corruption. In light of these findings, and given the critical link between preemptive bribery and information, it is useful to know whether preemptive bribery can still occur, or whether the regulator can safely ignore preemptive bribery because asymmetric information makes

[1]Note that in their paper asymmetric information is between multiple supervisors whereas in our model it is between the supervisor and the agent.

it unlikely to occur. To address this issue, in this paper we develop a model to study preemptive bribery under asymmetric information. To our knowledge ours is the first attempt at fully understanding the implications of asymmetric information for preemptive bribery.

We consider and enforcement setting where firms belong to one of three types: zero waste (non-polluting), low waste, and high waste firms. Different levels of compliance attract different mandated fines. Supervisors can easily observe whether a firm is a zero waste firm or not, but cannot distinguish between low and high waste firms[2]. Of course, the supervisor can exert costly effort to gather evidence regarding the firm's compliance level and as a result may learn the actual level. Thus, the size of the ex-post bribe can be determined by bargaining mechanisms under symmetric information. In contrast, preemptive bribery occurs before the supervisor observes whether the firm's actual type is known. Given this information structure, we set up the game as a signalling game with incomplete information, where the firm makes a bribe offer which the supervisor can accept or reject. Acceptance leads to preemptive collusion where the accepted bribe is exchanged and the supervisor does not undertake evidence gathering. Rejection leads to the supervisor exerting effort to collect evidence and subsequently engaging in ex-post bribery or truthful reporting.[3] We characterize the entire set of (Bayesian Nash) equilibria of this game and show that despite the presence of asymmetric information, *it is not possible to prevent preemptive collusion completely.* As is well known, signalling games admit a plethora of equilibria. We can have equilibria where both low and high waste firms pay preemptive bribes and are never prosecuted, or equilibria where high waste firms pay a preemptive bribe and are never prosecuted while low waste firms are prosecuted. Using standard refinement criteria we show that there is a unique equilibrium, where the high waste firms always engage in preemptive bribery and escape prosecution, while the low waste firms are sometimes prosecuted. Hence, informational asymmetry has limited deterrence for some of the firms.

An important issue to address when studying preemptive bribery under asymmetric information is whether the bribing process can reveal some information about the firm's level of waste, and whether this information can make the supervisor's investigation more effective at a later stage in the game. We extend our basic model above to allow for the possibility

[2] An almost identical information structure is found in Celig (2008).

[3] The informational structure of this game is similar to Reinganum and Wilde's (1986) analysis of litigation and settlement. In this model only the plaintiff knows the true level of damages. and makes a settlement demand based on the true level of damages. The defendent infers the plaintiffs true damage level, and must decide whether to settle or let the case go to trial.

that "knowledge" of a firm's type makes it easier for the supervisor to collect evidence for prosecuting the firm. This possibility, referred to as the *knowledge criterion*, affects the preemptive bribery game drastically. We show that preemptive bribery can be eliminated completely in the sense that the unique equilibrium outcome satisfying the knowledge criterion is the outcome where none of the high waste firms successfully engage in preemptive bribery. Thus our paper shows that whether informational asymmetries reduce the feasibility of preemptive bribery or not depends largely on whether this information can be utilized by the supervisor to make subsequent inspections more effective.

Our paper builds on the existing small literature on preemptive bribery. The possibility of preemptive bribery and its efficiency implications have been studied by Bac (1998), Bag (1997) and Samuel (2009). They show that even when it is optimal to deter ex-post bribery, preemptive bribery might be tolerated becasue it is efficient. Moreover, when bribery can occur both preemptively and ex-post, it can be shown that policies eliminating ex-post bribery may incentivize preemptive bribery. But, in these papers the informational aspects of preemptive bribery are ignored. For example, Samuel (2009) avoids the information problem with preemptive bribery by distinguishing between "hard" and "soft" information.[4] Specifically, he assumes that the supervisor knows whether the firm is compliant or not without exerting effort, but that this information is "soft". In order to obtain hard evidence regarding the firm's non-compliance, which is necessary in order to impose a fine on the firm, supervisors must exert effort. Thus, the preemptive bribe is determined within a complete information setting since the firm and the supervisor know the exact level of compliance, although this information is soft.

More importantly, our results regarding the incentives for preemptive bribery stand in sharp contrast to results in the existing litearture. Specifically, Bac (1998) and Samuel and Lowen (2010) show that improving the supervisors ability to monitor the firm, or lowering the supervisor's cost of monitoring, encourage preemptive bribery. Thus, improvements in the ability of the supervisor to obtain hard information regarding the firm's type can sometimes encourage corruption. In contrast, in our model with incomplete information, improving the supervisors ability to obtain hard information discourages bribery and increases the frequency that some firms will be prosecuted. Additionally, we show that raising the fines

[4] Hard information refers to information that is (costlessly) verifiable by third parties (see Baliga (1999), Tirole (1992) for a discussion of this issue). Relatedly, Khalil et al. (2010) study the role of hard and soft information on bribery and extortion. In contrast to other papers, they assume that information is "hard" when the supervisor acts alone, but is "soft" for the supervisor, firm coalition because they collude to fabricate evidence.

for high waste firms can reduce the frequency of bribery among low waste firms. This is in contrast to nearly all the previous literature on preemptive corruption, where raising the fine unambiguously encourages bribery.

Our result concerning the importance of information for the feasibility of preemptive bribery is related to a few other papers on corruption and crime. Motta (2009) studies preemptive bribery under asymmetric information in a model of tax evasion. In his model the supervisor only knows the distribution of incomes, but not the income of an individual tax payer. Therefore, in contrast to our paper where the preemptive bribe may differ according to the level of compliance, in his paper the supervisor chooses a single preemptive bribe that maximizes the overall gains from preemptive bribery. Thus, the preemptive bribe does not provide any information regarding the tax payer's type, and consequently, none of the key findings regarding preemptive bribery are altered by the presence of asymmetric information. Similarly, Marjit et al. (2000) study a model of crime where a law enforcer chooses a level of effort in order to detect a crime, and where the probability of detecting a crime is increasing in the enforcer's level of effort. Potential criminals differ in their ability to avoid detection, thus when law-enforcers can observe this ability, they exert more effort towards detecting higher ability criminals. When the law enforcer cannot observe an individual's ability to avoid detection, but only knows the overall distribution of abilities then the law-enforcer must choose a single level of effort for all agents. In this case the asymmetric information can weaken the intensity of enforcement, depending on the distribution of abilities. Finally, our work is related to Ryvkin and Serra (2012) who study bribery within the context of bureaucrats who illegally provide a public good in exchange for a bribe. In their model bribery takes place under incomplete information because an individual's moral cost of paying or accepting a bribe is unknown. Bribery is modeled as a double auction, following the model of bargaining under assymetric information due to Chatterjee and Samuelson (1983). They show that relative to the case with complete information, corruption is less likely to occur under incomplete information because bribe payers under-bid, and bribe takers over-bid, relative to the true value they are willing to pay (accept). In contrast, our paper addresses the problem of bribery within a regulatory setting with endogenous levels of inspection effort. We attempt to understand how the bribing process can itself reveal some information about the firm's level of non-compliance, and whether this can in turn influence the effectiveness of inspections.

Following the introduction, the second section describes our model under complete information. The third section studies extends this to incomplete information. In section 4 we introduce the knowledge criterion and discuss how preemptive bribery is affected and the final section concludes.

2 Complete Information: the Benchmark Case

Consider a model with three risk-neutral players: the principal or regulator, the supervisor, and the firm. In our benchmark model, the regulator does not make any strategic decisions. Firms belong to one of three types (i): compliant firms with a waste level of (0), low-waste firms with a waste level of (l), and high-waste firms with a waste level of (h), so that $i \in \{0, l, h\}$. By assumption, $h > l > 0$. Among the polluting firms the proportion of l types is p and h types $(1-p)$ and each firm knows its type. Supervisors are hired by the regulator to investigate so that firms can be penalized according to their level of waste. Since this game is one with complete information, the supervisor immediately observes the firm's type, therefore, the supervisor's information set is, $I^C = \{\{0\}, \{l\}, \{h\}\}$. Although the supervisor observes the firm type, this information is soft and he must exert effort in order to obtain hard evidence to use in its report to the regulator. By exerting costly effort $E > 0$ the supervisor can, with probability $\mu \in (0,1)$, obtain hard evidence regarding the firm's waste level $\{l, h\}$, and with probability $(1-\mu)$ obtains no evidence $\{\phi\}$. This report is denoted by θ, where $\theta \in \{l, h\} \cup \{\phi\}$. The report results in the firm being fined F_i, $i = \{l, h\}$, and the supervisor receives a reward $r_i \cdot F_i$. We assume that $F_h > F_l > 0$ and that $r_h = r_l = r$, and that evidence is needed only for firms with positive waste, so that lack of any evidence, ϕ, leads to imposition of $F_0 = 0$.[5] Finally, we assume that the following condition always holds so that we may ignore cases where E is so large (or μ so small) that the supervisor receives a negative payoff by exerting effort and collecting evidence.

$$\mu r F_l - E \geq 0 \tag{1}$$

Supervisors and firms are corruptible and may choose to exchange bribe instead of the fine. In any given interaction between the firm and the supervisor, bribery may occur at two stages: preemptively, that is before the supervisor has discovered the firm's type, or ex-post, that is after the supervisor discovers the firm's type. Under ex-post bribery the

[5]Note that extortion is not feasible in our model because of the requirement of hard evidence for any reporting. An l type cannot be reported as an h type without evidence and we assume that evidence can not be 'cooked'.

supervisor gathers evidence but submits a report $\theta = \phi$ in exchange for a bribe. Thus, conditional on the supervisor exerting E, ex-post corruption can occur only with probability μ; that is only if the supervisor finds hard evidence about the firm's pollution. In contrast, with preemptive bribery the supervisor commits not to investigate further (by not exerting effort) in exchange for a bribe. This obviously means that the firm will not be fined ever, as there is no hard evidence. If an ex-post bribe is exchanged there is some probability λ with which the regulator discovers that a bribe has been exchanged. In the event of this leak, the supervisor is penalized T_i and the firm must pay the (avoided) fine $F_{i.}$ However, we assume that preemptive collusion is immune to such exogenous detection because the detection probability is likely to be higher when hard evidence is present but suppressed compared to the case where evidence has not been gathered.[6] Under the assumption of sequential rationality we solve for the sub-game perfect Nash equilibrium of this game. That is, we first analyze the ex-post bribery game, and then preemptive bribery.

First consider the ex-post bribery game. Since bribery is discovered with probability $\lambda > 0$, and the firm pays only F_i in the absence of any penalty for bribe giving, the type i firm will gain by offering a bribe less than $(1 - \lambda)F_i$. On the other hand, supervisor will accept any bribe offer that is greater than $r \cdot F_i + \lambda T_i$. Thus ex-post bribe will be exchanged if $F_i(1 - r) \geq \lambda(T_i + F_i)$. Clearly, by raising r to some $r > r^{/}$, this condition can be reversed and ex-post bribery eliminated. If penalty for bribery T is fixed, $r^{/}$ will be different for low and high pollution levels. Alternatively, if $T_i = TF_i$, the condition for preventing ex-post collusion is,

$$r \geq r^{/} = 1 - \lambda(1 + T). \tag{2}$$

For the remainder of this paper, we shall assume that (2) is always satisfied and focus on incentives for preemptive bribery.

We now turn to the game with preemptive bribery. Let G^C denote the preemptive bribery (and subsequent investigation) game. We assume that G^C follows a simple ultimatum game where the firm always makes an offer, which the supervisor chooses to accept or reject. Although, these assumptions may appear constricting, the key qualitative results are unlikely to be affected.[7] Acceptance of the bribe offer implies that the supervisor will not

[6]This assumption is mainly to focus on situations where it is difficult to prevent preemptive collusion. See Samuel (2009) for a model where both forms of bribery are subject to detections.

[7]Our model implies that the firm possesses all the bargaining power. Most bribery games determine the

investigate the firm any further, and rejection means that the supervisor exerts costly effort E to investigate and collect evidence (with probability μ). In the absence of any hard evidence, $\theta = \phi$ and the firm does not pay any fine. If hard evidence is obtained, then given (2) the firm pays F_i in fines and the supervisor gets rF_i. A polluting firm of type i will, therefore, offer $(\mu r F_i - E)$ that will be accepted by the supervisor. Since preemptive bribery cannot be detected, for any $r \leq 1$ preemptive collusion will not be deterred regardless of whether ex-post collusion is deterred or not. Hence our focus is on the case, $r^{/} < r < 1$. Before proceeding further, we find it useful to denote U_i for $i = \{0, l, h\}$, as the expected payoffs to a firm of type i, and V as the (expected) payoffs to the supervisor, in game G^C. Equilibrium payoffs are denoted by U_i^*, V^*. In the benchmark case, we have, $U_i^* = -[\mu r F_i - E], i = l, h$ and $U_0^* = 0$.

3 Incomplete Information and Preemptive Collusion

When the supervisor is unable to distinguish between the l and the h types, preemptive collusion involves an uninformed supervisor. In this game with incomplete information, the supervisor only observes whether the firm is a zero waste firm (of type 0) or positive waste firm (of type l or h). Thus, the supervisor's information set I^A now has the partition $\{\{0\}, \{l, h\}\}$. By exerting costly effort $E > 0$ the supervisor can, with probability $\mu \in (0, 1)$, obtain hard evidence regarding the firm's waste level. Note that possession of hard evidence implies knowledge of the firm's type but the reverse is not true.

[**Figure 1 here**]

The above bribe game, which we denote by G^A, is a signalling game (Figure 1) where a firm whose type is unknown to the supervisor makes a bribe offer, and where p is the supervisor's prior belief that the firm is of type l. Following a preemptive bribe offer B, the supervisor updates its belief about the firm's type, where q denotes the supervisor's posterior belief that the firm is of type l, $q(B) = prob(i = l \mid B)$. Besides the bribe, we assume that the supervisor does not receive any other signals. A firm of type i's strategy is denoted by the bribe offer B_i, where $B_i \geq 0$, while the supervisor's strategy is denoted by $a \in \{0, 1\}$,

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bribe within a Nash bargaining framework with equal bargaining power. However, this bargaining solution cannot be extended easily to incomplete information settings. As an alternative to the above assumption, we have considered another variant of the ultimatum game where the supervisor and the firm each make an offer (or bribe ask) with probability .5. None of our key results are affected by this change.

where $a = 1$ denotes acceptance of the bribe.[8] Rejection, $a = 0$, leads to the supervisor putting in the required effort to collect the hard evidence. Let $\rho(a \mid B) \equiv \rho(B)$ be the probability that a bribe offer B will be accepted.

We denote the game's strategy profile as $\sigma = (B_l, B_h, \rho(B))$, and shall consider sequential equilibria $(\sigma^*, \widetilde{q}\,)$ where σ^* is sequentially rational given system of beliefs $\widetilde{q}$, and $\widetilde{q}$ is consistent with σ^*, Bayes' law, and the given prior p. First, we examine whether the no-collusion outcome without any preemptive bribery is completely prevented. Then, we consider two types of preemptive bribe equilibria: (1) pooling equilibria where both types of firms offer the same positive bribe and the supervisor accepts the bribe, and (2) separating equilibria where h types offer a separating bribe B_h^* and the l types offer B_l^*, and the supervisor accepts the higher bribe from the h type while rejecting the lower bribe with positive probability. In the separating equilibrium, there is preemptive collusion with the h type but the l type is being investigated and penalized with positive probability.[9]

As is well known, these games admit many equilibria which are often supported by unreasonable out-of-equilibrium beliefs. We use a version of the universal divinity criterion (Banks and Sobel (1987), Cho and Sobel (1990)) to refine the set of equilibria. Refinement in this context essentially eliminates types for a certain strategy B if they are unlikely to have deviated to that strategy B (given the other players' best response to B). We use the following condition, denoted as $D1$, to refine the set of equilibria (see Fudenberg- Tirole (1991)).

Consider any particular equilibrium $(\sigma^*, \widetilde{q}\,)$ and let U_l^*, U_h^* be the equilibrium payoffs of the two types in the game G^A. Type i will benefit from deviating to offer a bribe B if $U_i(B, \rho) > U_i^*$. Let P be the set of mixed best responses by the supervisor for any beliefs q over types. Let $D(B, i)$ be the set of mixed best responses ρ so that type i benefits from deviating. That is,

$$D(B, i) = \{\rho \in P \text{ s.t. } U_i(B, \rho(B)) > U_i^*\}, i = l, h \tag{3}$$

Similarly, define $D^0(B, i)$ as the set of best responses by the supervisor so that type i is

[8] In the text, we shall focus mostly on pure strategy bribe offers by the firm, except the semi-separating equilibrium where firms can randomize over different bribe offers. See the appendix for details.

[9] In the appendix, we also consider a third case, a semi-separating equilibrium where the both types engage in successful preemptive bribery with positive probability, but the probability of being investigated is higher for the l types.

indifferent between the equilibrium play and deviation to offer B. Then,

$$D^0(B,i) = \{\rho \in P \text{ s.t. } U_i(b,\rho(B)) = U_i^*\}, i = l,h \tag{4}$$

Condition D1 requires that a type i is deleted for deviation B if $\exists j \neq i$ s.t.

$$\{D(B,i) \cup D^0(B,i)\} \subset D(B,j) \tag{5}$$

The condition requires that type i is not likely to have deviated to offer B if there exists another type j such that whenever type i finds it profitable to deviate, so does type j, but the reverse is not true. An equilibrium is rejected if out of equilibrium beliefs fail to satisfy this condition.

3.1 Preventing collusion

Recall that in the complete information benchmark case, it is not possible to prevent preemptive collusion by either type of firms, whenever $r < 1$. In the incomplete information case, it can be shown that it not possible to eliminate collusion by both types. We shall argue that the no-collusion outcome cannot be sustained as an equilibrium.

For the no-collusion outcome to be an equilibrium, it must be the case that $B_l^* = B_h^* = 0, q = p, \rho(B) = 0, \forall B < \mu r F_h - E$.[10] Observe that it is not rational for the supervisor to reject any bribe offer exceeding $\mu r F_h - E$. Thus, the no-collusion outcome cannot be supported as an equilibrium, since the h type will always deviate and offer $\mu r F_h - E$ which will be accepted. Since $r < 1$, we have $\mu r F_h - E < \mu F_h$, and such a deviation is always profitable.

Proposition 1 *Let $1 > r \geq r^/$ so that ex post collusion is not feasible. In the incomplete information environment, it is never possible to prevent preemptive bribery completely.*

This establishes that the presence of asymmetric information in itself is not sufficient to deter preemptive bribery. The regulator cannot ignore this form of collusion when asymmetric information is present. However, we shall see that compared to the benchmark case in Section 2, there is some deterrence of preemptive bribery.We shall show that the h types

[10] More generally, we can have $B_l^* = B_h^* = B < \mu r F_h - E$. But it does not affect the main argument.

will always engage is some form for preemptive bribery in any equilibrium. The extent to which the l types engage in bribery depends on the particular equilibrium we focus on.

3.2 Pooling: Preemptive bribery by both types

There are equilibria where both types of firms are able to enter into preemptive collusion with the supervisor. Consider a pooling equilibrium with positive bribes $B_l = B_h = B^* > 0$, the supervisor accepts B^*. Let $V^R(q)$ be the expected payoff to the supervisor from rejecting a bribe offer when its posterior belief that the firm is type l is given by q. In any pooling equilibrium bribery does not reveal any information about the firm's type. Thus, the supervisor's posterior beliefs are $q = p$. Therefore, the pooling bribe B^* must satisfy:

$$B^* \geq V^R(p) = \mu r[pF_l + (1-p)F_h] - E.$$

This bribe must also be individually rational for the low types, therefore,

$$B^* < \mu F_l.$$

Combining the two previous inequalities, it follows that a pooling equilibrium with preemptive bribery can exist only if

$$\mu[(rF_h - F_l - rp(F_h - F_l)] < E. \tag{6}$$

If the above condition is satisfied, then there exists a strategy profile σ, and system of belief $\widetilde{q}$, such that $(\sigma, \widetilde{q}\ )$ is a sequential equilibrium.[11] This strategy profile is,

$$\begin{aligned} B_i^* &= B^*, i = l, h,\ V(p) \leq B^* \\ \rho^*(B) &= \begin{cases} 1, & \forall B \geq B^* \\ 0, & \forall B < B^*. \end{cases} \end{aligned}$$

It should be noted that there is in fact a multiplicity of such pooling equilibria. Any bribe B^* such that $V^R(p) \leq B^* < \min\{\mu F_l, \mu r F_h - E)\}$ can be supported as an equilibrium. The system of beliefs $\widetilde{q}$ supporting this equilibrium is given by,

[11] We shall use P, S and NC to denote pooling, separating and the no-collusion cases.

$$\widetilde{q} = \begin{cases} p, B = B^* \\ 0, \forall\ V^R(p) < B < B^* \\ p, \forall\ B \leq V^R(p) \end{cases}$$

It can be verified that $\rho^*(B)$ is optimal given $\widetilde{q}$.[12] Both types offering bribe B^* is also optimal given ρ^*. The system of belief given by $\widetilde{q}$ above is also consistent. However, as we show in the appendix that the above out-of-equilibrium beliefs specified by $\widetilde{q}$ are not reasonable in the sense that these beliefs do not satisfy condition $D1$.

3.3 Separating bribes

We consider two cases of separating equilibrium. In the first class of separating equilibrium, only the h type is able to engage in bribery and avoid prosecution. In the second class, both types engage in preemptive bribery (with different bribe offers) but the l type is prosecuted with some probability while the h type escapes prosecution.

3.3.1 Preemptive bribery by the h type only

Assume that $\mu r F_h - E \geq \mu F_l$. Consider the separating equilibrium where the high type separates itself from the low type. Define $B_l^* = 0$ and $B_h^* = (\mu r F_h - E)$. It can be shown that there exists a strategy profile σ^* and system of belief $\widetilde{q}$ such that $(\sigma^*, \widetilde{q}\ )$ is a sequential equilibrium. The strategy profile σ^* is given by

$$\begin{aligned} B_l^* &= 0,\ B_h^* = \mu r F_h - E \\ \rho^*(B) &= \begin{cases} 1, \forall B \geq B_h^* \\ 0,\ \text{otherwise.} \end{cases} \end{aligned} \tag{7}$$

The corresponding belief system $\widetilde{q}$ is given as follows:

$$\widetilde{q} = \begin{cases} 1, B = 0 \\ 0,\ \forall B > 0. \end{cases} \tag{8}$$

[12]Let $p^/$ satisfy $V^R(p^/) = B^*$. We need $q(B) \leq p^/$ for all $B < B^*$. Since $V^R(p) < B^*$, we have $p^/ < p$.

The supervisor believes that any positive bribe offer must be from the h type. Given this belief, the supervisor will not accept any bribe which is less than $\mu r F_h - E$. This is the payoff the supervisor gets from rejecting a bribe offer when faced with the h type firm. The l types pay no bribe and face investigation and do not benefit from deviating given the beliefs and strategy of the supervisor.

An interesting implication of the separating equilibrium is that the h types are able to engage in preemptive bribery, where as the l types are investigated. Since we have assumed that ex post collusion is being deterred, these l types will be prosecuted. Thus, in a sense there is partial enforcement in this case. However, as we show in the Appendix, this equilibrium also fails to satisfy condition $D1$.

3.3.2 Limited bribery and partial prosecution

We can have several separating equilibria with the l type offering a non zero bribe. Unlike the previous case (3.3.1), the existence of these equilibria does not depend on whether $\mu r F_h - E \geq \mu F_l$ or not. Here both types offer different bribes, but these offers are accepted with different probabilities. The h type's higher offer is accepted with probability 1, but the l type's offer is rejected with some positive probability. Define $B_l^* = \mu r F_l - E$ and $B_h^* = (\mu r F_h - E)$. The supervisor's strategy is given by,

$$\rho^*(B) = \begin{cases} 1, \text{ for } B \geq B_h^* \\ x, \text{ for } B = B_l^* \text{ where } x = \frac{\mu F_h + E - \mu r F_h}{\mu F_h + E - \mu r F_l}, 0 < x < 1 \\ 0, \ otherwise. \end{cases}$$

The corresponding belief system $\widetilde{q}$ is given as follows,

$$\widetilde{q} = \begin{cases} 0, B > \mu r F_l - E \\ 1, otherwise. \end{cases} \tag{9}$$

Proposition 2 *Let $r \geq r^/$ so that ex post collusion is not feasible. In this limited information environment, there exists an equilibrium where the h type engages in preemptive bribery and is never prosecuted and the l type engages with bribery but is prosecuted with positive probability $x \in (0,1)$. This is the only equilibrium satisfying condition $D1$.*

Proof. It is easy to verify that the strategy profile and beliefs specified above constitute an equilibrium.[13] The h type is indifferent between offering B_h^* and B_l^*, hence it has no incentive to deviate. The l type does not benefit from deviation either. Any bribe below $\mu r F_l - E$ will be rejected and will lead to a payoff of $-(\mu F_l) < -[x(\mu r F_l - E) + (1-x)\mu F_l]$. It can be verified that it will also be strictly worse off by offering any bribe $B \geq B_h^*$. For the supervisor, rejecting any bribe offer lying between $\mu r F_l - E$ and $\mu r F_h - E$ is optimal because the supervisor believes that such offer would have come only from the h type. Note that any offer below $\mu r F_l - E$ will be rejected irrespective of the belief about the types. We can verify that beliefs satisfy condition $D1$. Recall that equilibrium payoffs are

$$U_h^* = -[\mu r F_h - E], U_l^* = -[x(\mu r F_l - E) + (1-x)\mu F_l]. \tag{10}$$

Now consider a deviation to bribe $B > \mu r F_l - E$. We can find the the set of mixed best responses by the supervisor for which such a deviation would yield higher payoffs compared to the equilibrium payoffs for the two different types. Using 5,

$$\begin{aligned} D(b,h) &= \{\rho \in P \mid \rho > \rho_h = \frac{\mu F_h + E - \mu r F_h}{\mu F_h - B}\}, && (11) \\ D(b,l) &= \{\rho \in P \mid \rho > \rho_l = \frac{x(\mu F_l + E - \mu r F_l}{\mu F_l - B}\} && (12) \\ where\ \ x &= \frac{\mu F_h + E - \mu r F_h}{\mu F_h + E - \mu r F_l} \end{aligned}$$

Since $(\rho_h - \rho_l) = (\mu r F_l - E - B)(\mu F_h - \mu F_l) < 0, \forall B > \mu r F_l - E$ it follows that $\{D(B,l) \cup D^0(B,l)\} \subset D(b,h)$. Hence according to D1, given any bribe offer in excess of $\mu r F_l - E$ the supervisor should believe that the offer would have been made by the h type rather than the l type. This is what the beliefs as given in 9 specify. In the Appendix we show that no other equilibrium satisfies condition D1. ∎

This equilibrium shows that the l types does get prosecuted with some probability. Incomplete information, in this sense, does reduce preemptive bribery and raises prosecution. Further, the following proposition shows that the lack of information regarding the firm's type does affect many previous results concerning preemptive bribery.

[13] We have not provided any arguments regarding its existence. To show that such a construction exists, it suffices to note that $0 < x < 1$. Suppose $p = 1/2, F_h = 40, F_l = 20, E = 2, \mu = 3/5, r = 3/4$. The h type offers 16 which is accepted, the l type offers 7 which is accepted with probability 8/17. So the l type is prosecuted with probability 9/17.

Proposition 3 *In an equilibrium that satisfies D1, the following comparative statics hold. The likelihood of prosecution of the l types is increasing in r, μ, and F_h, but decreasing in F_l. The likelihood of prosecuting the h types in unaffected by changes in these parameters.*

Proof. From the expression for x in Proposition 1, we can verify that $\frac{\partial x}{\partial r} < 0, \frac{\partial x}{\partial \mu} < 0, \frac{\partial x}{\partial F_l} > 0$ and $\frac{\partial x}{\partial F_h} < 0$. Since the probability of prosecution is simply $(1 - x)$, the claim in the proposition easily follows. ■

These results are interesting in light of previous results regarding preemptive bribery (as discussed in Bag 1998, Samuel 2009). Specifically, when preemptive bribery occurs under full information, an increase in the supervisor's ability to monitor the μ, an increase in E, and an increase in f always increase the incentives for preemptive bribery. In contrast, with incomplete information an increase in μ reduces the frequency of preemptive bribery by the low types (by lowering x), while not affecting the incentives for bribery among the high types. However, an increase in E raises x thereby increasing the frequency of preemptive bribery among the low types. Further the fines have opposing effects in that an increase in F_l increases the frequency of bribery among l types, whereas an increase in F_h decreases the frequency of bribery among l types, but neither of these fines impact the likelihood of bribery among h types.[14] We discuss the implications of these results for corruption policy in the conclusion.

4 Knowledge Criterion and Preemptive bribery

In the previous section, we have implicitly assumed that the probability, μ, of gathering hard information or verifiable evidence is independent of whether the supervisor is knowledgeable about the firm's type or not. This assumption is present in different forms in much of the literature. In many models (i.e. Mookherjee and Png 1995), all information is hard information and hence there is no difference between detection of types and evidence gathering. In models where a distinction between hard and soft information is made (i.e. Samuel 2009), the supervisor always knows the types but to gather hard information (or what we have also referred to as verifiable evidence) the supervisor needs to incur positive cost. In contrast, here the supervisor does not know the types to start with but it can learn about the types

[14] This also opens up the possibility that the regulator might impose differet fines for firms even when they generate the same social harm, in order to create artificial types.

without (and before) collecting evidence.[15] The key question here is: does prior knowledge of the types make it easier to collect evidence? We believe that in many settings it does. For example, a suspect in a criminal trial may admit to the crime. Often this admission of guilt is inadmissible in court, nevertheless this knowledge can make it easier for a detective to find hard evidence against the suspect. Similarly, it is common for an investigative journalist to know of a particular political scandal (perhaps because the knowledge is obtained through "unnamed sources"). However, this very knowledge can make it easier for the journalist to obtain hard evidence regarding this scandal.

In this present context in a separating equilibrium the act of exchanging a bribe itself must reveal something about the firm type since each type of firm offers a different bribe. Although this information may not be hard (i.e. third party verifiable), it will make it easier for the supervisor to obtain hard evidence regarding the firm's type. We operationalize the concept that knowledge translates into more effective evidence gathering, through the following Knowledge Criterion.

Knowledge Criterion: *Suppose the supervisor believes the firm to be of a certain type with probability one, the probability (μ') of obtaining hard information against this particular type, upon exerting effort E, is always higher than the probability (μ) of obtaining hard information against a type of firm that the supervisor is not sure about.*

In this section we require that all equilibria (discussed earlier) should satisfy the *Knowledge Criterion (KC).* In other words, we require that $\mu' = \mu(1) > \mu(q)$, *for* $q < 1$.For simplicity we assume that $\mu' = 1$. It is clear that many of the equilibria discussed earlier will be affected by this criterion. Note that previously, the h types were always able to separate from the other type and engage in preemptive bribery. But now there is a trade-off, once revealed, the expected rewards to the supervisor will be higher and the minimum bribe required to engage in preemptive bribery will also be higher. This will act as a disincentive for preemptive collusion. The following proposition confirms this.

Proposition 4 *Suppose $r > \mu$ & $r > r'$. The no-collusion outcome can be implemented as the unique equilibrium of the preemptive bribery game satisfying the Knowledge Criterion if the fine for the h type can be raised sufficiently.*

Proof. Note that we continue to assume $r \geq r'$ so that *ex post* collusion is always

[15] It is quite common for agents, in various economic settings, to learn or know through communication, signalling and different methods of inference.

prevented. First, we show that the no-collusion outcome can be an equilibrium. Consider the equilibrium strategy profile

$$\sigma^*_{NC} : B^*_l = 0, B^*_h = 0, \rho^*(B) = 0, \forall B \leq rF_h - E. \tag{13}$$

The corresponding belief system is given by,

$$\widetilde{q}_{NC} = \begin{cases} p, \ B = 0 \\ 0, B > 0. \end{cases}$$

It is easy to verify that $(\sigma^*_{NC}, \widetilde{q}_{NC})$ is an equilibrium if $\mu F_h \leq rF_h - E$. By not entering in to a preemptive bribery deal, the firm faces full penalty F_h, but with a reduced probability $\mu < 1$. With preemptive bribery, given *KC*, it has to pay a higher bribe $rF_h - E$. In the absence of *KC*, the minimal separating offer by the h type is $\mu rF_h - E$, whereas with *KC* this goes up to $rF_h - E$. Hence to guarantee the existence of this equilibrium we need

$$r \geq \mu + \frac{E}{F_h}, or \ F_h \geq \frac{E}{r - \mu}. \tag{14}$$

Hence the h type will prefer to be inspected if condition (14) is satisfied, $rF_h - E > \mu F_h$, which reduces to $(r - \mu)F_h > E$. Thus we can not have any separating equilibrium.

Secondly, as discussed earlier all the pooling equilibria (**??**) can be eliminated if 6 is reversed, that is,

$$F_h \geq F^{/}_h, \text{ where } \mu[(rF^{/}_h - F_l - rp(F^{/}_h - F_l)] = \mu F_l. \tag{15}$$

Hence, if we choose $F_h \geq \max(F^{/}_h, \frac{E}{r-\mu})$, the no-collusion equilibrium is unique. ■

This shows that a combination of high rewards for the supervisor and high fines for the h type firms can deter both forms of collusion. Our analysis relied heavily on the regulator's ability to set F_h at a sufficiently high level. This may not be feasible for various reasons, for example, fines might be subject to some limited liability constraints. Moreover, the knowledge criterion makes a significant impact only when μ is not too large. *As μ is raised preemptive bribery becomes more attractive and it may not be possible to guarantee the no-collusion outcome.*

5 Conclusion

The goal of this paper is to understand the implications of the informational environment in which bribery takes place and study its relationship to the timing of bribery (i.e. preemptive or ex post). We show that the incentives for preemptive bribery are strongly influenced by introducing asymmetric information. However, the degree of influence depends on whether the prior knowledlge of types makes it easier to collect evidence (knowledge criterion).

In the absence of the knowledge criterion asymmetric information prevents preemptive bribery, but only to a limited extent. Specifically, with asymmetric information h types always engage in preemptive bribery while l types do so with some probability and are prosecuted the rest of the time (Proposition 2). To the extent that it is socially desirable to prevent preemptive bribery, it is clear that the presence of two types with asymmetric information, and higher fines for one type, has made it possible to prevent some bribery. However, an outcome in which neither types (ever) engage in bribery cannot be sustained as an equilibrium.

The results of Proposition 2 are interesting in light of recent empirical findings by Babu et al. (2012) who find that smaller firms are prosecuted more often, while larger firms are able to bribe their way out of being prosecuted. In our model high polluting firms are always able to separate themselves from small firms, and are never prosecuted. Thus, Proposition 1 offers some theoretical support for this finding.

We also show that many results which apply to preemptive bribery under full information are no longer valid under asymmetric information (Proposition 3). Bac (1998), Bag(1997), and Samuel (2009) show that an improvement in the supervisors' ability to monitor the firm, or an increase in the cost of monitoring E, always encourages preemptive bribery. In contrast, here an improvement in the supervisors monitoring technology reduces the frequency of preemptive bribery, whereas an increase in the cost of monitoring increases the frequency of preemptive bribery. Thus, in contrast to these previous papers who argue that improvements in the monitoring technology may not be desirable since they encourage bribery, here we show that in the presence of asymmetric information, improvements in monitoring technology may be desirable.

A second important distinction from the results under full information is regarding the fines for the original act of non-compliance. Under full information an increase in the fine always encourages bribery (among all types). In contrast, in our model an increase in the fine for the h types *reduces* the likelihood of bribery among the *low types,* while an increase in the fine for the l types increases the likelihood of bribery among the l types. Thus, by raising the fine of the h types the frequency of prosecution of the l types can be improved.

The implications of asymmetric information for preemptive bribery is magnified under the knowlege criterion. Without the kc preemptive bribery benefits at least the h types because the coaltion benefits from avoiding costs E, without any tradeoff. With the knowledge criterion, knowledge obtained through the bribing process makes evidence gathering more effective. Consequently, the h types' incentive to separate and engage in preemptive bribery now comes at a cost, and the minimum bribe required to separate is significantly higher under the knowledge criterion. Thus, in contrast to the case without the knowledge criterion, preemptive bribery can be eliminated completely under certain reasonable conditions.

6 Appendix

In the following paragraphs we examine the various equilibria discussed in the text to see whether the out-of-equilibrium beliefs specified by these equilibria are deemed reasonable. As mentioned in the text, we consider a version of the Universal Divinity criterion and refer to it as condition $D1$.

1. *Semi-separating equilibrium*

Besides the pooling and separating equilibria, we can also have equilibria with semi-separation. Assume $\mu r F_h - E > \mu F_l$. The $h - type$ randomizes between separating by offering a high bribe (B_h) and pooling with the $l - type$ with a lower bribe (B^*). Let $\theta(B)$ be the probability that the $h - type$ offers bribe B. The supervisor accepts the higher bribe offer B_h with probability one, but randomizes between acceptance and rejection following bribe offer B^*. It can be shown that the following strategy profile σ^P, and system of belief $\widetilde{q}^P$, constitute a sequential equilibrium. The strategy profile σ^* is given by

$$
\begin{aligned}
B^* &= \mu F_l, B_h = \mu r F_h - E, \\
\theta^h(B^*) &= \frac{(1-r)\mu F_h + E}{\mu(F_h - F_l)}, \theta^l(B^*) = 1, \theta^h(B_h) = 1 - \theta^h(B^*) \qquad (16) \\
\rho(B) &= 1, \forall B \geq B_h \\
&= x,\ B = B^* \text{ where } x = \frac{p(F_l + E - rF_l)}{(1-p)(rF_h - F_l - E)} \\
&= 0,\ \text{otherwise.}
\end{aligned}
$$

The corresponding beliefs are given by

$$
\begin{aligned}
q(B) &= 0, \forall B \geq \mu r F_h - E \qquad (17) \\
&= \widehat{q} = \frac{rF_h - E - F_l}{rF_h - rF_l} > 0, B = \mu F_l \qquad (18) \\
&= 0, \forall B < \mu F_l
\end{aligned}
$$

Verification of equilibrium is easy.[16] Faced with a bribe of μF_l, the supervisor believes that the probability that the firm is $l - type$ is $\widehat{q} < 1$. Given $\widehat{q}$, the supervisor is indifferent between accepting and rejecting. However, note that for this to be an equilibrium, the supervisor must not accept bribe below μF_l. Hence we require the supervisor to believe that a bribe offer B, $\mu r F_l - E < B < \mu F_l$, would be more likely to have been made by h type.[17] This belief is not reasonable and we can verify that it does not satisfy $D1$.

Fix this equilibrium and a deviation to bribe b, $\mu r F_l - E < B < \mu F_l$. Equilibrium payoffs of the two types are $U_h^* = -[\mu r F_h - E], U_l^* = -[\mu F_l]$.Type h would deviate to b if $\rho b + (1-\rho)\mu F_h < \mu r F_h - E$ where ρ is the probability that b will be accepted. Hence $J_h = \{\rho \in P \mid \rho > \rho_h = \frac{\mu F_h + E - \mu r F_h}{\mu F_h - b} < 1\}$. For the l type deviation to b is profitable iff $\rho b + (1-\rho)\mu F_l < \mu F_l$. Hence $J_l = \{\rho \in P \mid \rho > 0\}$. Clearly, $J_h \subset J_l$. Hence the l type is more likely to have deviated to b. Beliefs specified in () do not satisfy this.

[16]Consider the earlier example (footnote). Suppose $p = 1/2, F_h = 40, F_l = 20$, $E = 2, \mu = 3/5, r = 3/4$. The h type offers 16 with probability 1/8 and offers 12 with probability 7/8. The l type offers 12 with probability 1.The supervisor accepts the higher offers with probability 1. It accepts the lower offer with probability 2/3. Faced with a bribe offer of 12, the supervisor believes the probability of the sender being $l-$type to be 8/15.

[17]Note that $\mu r F_l - E < \mu F_l$ since $r < 1$.

2. Separating Equilibrium

Suppose $\mu r F_h - E > \mu F_l$. Consider the separating equilibrium discussed in the text 7, $B^* = 0, B_h = \mu r F_h - E$. Equilibrium payoffs of the two types are $U_h^* = -[\mu r F_h - E], U_l^* = -[\mu F_l]$. Note that here payoffs are identical to the earlier semi separating case. Consider a deviation to bribe $b > \mu r F_l - E$. This case is identical to the case above and same arguments apply, $J_h(b) \subset J_l(b)$. Out-of-equilibrium belief $q(l \mid b) = 0$ is not consistent with $D1$.

Note that we do not have separating equilibria of this type when $\mu r F_h - E < \mu F_l$. The only separating equilibrium in such a case will be the one discussed Proposition 1.

3. Pooling Equilibrium

Let $\mu r F_h - E < \mu F_l$, note that it is a sufficient condition for the pooling equilibrium to exist. This implies that the necessary condition as given in 6 is satisfied. Consider the pooling equilibrium with $B_h^* = B_l^* = B^* = \mu r[pF_l + (1-p)F_h] - E$. This is the smallest possible equilibrium bribe in a pooling situation. Consider a deviation to bribe b, $\mu r[pF_l + (1-p)F_h] - E > b > \mu r F_l - E$. Equilibrium payoffs of the two types are $U_h^* = U_l^* = -B^*$. Like before we can find the set of mixed best responses by the supervisor so that deviation by the firm would be profitable. It is easy to check that $J_h(b) = \{\rho \in P \mid \rho > \rho_h = \frac{\mu F_h - B*}{\mu F_h - b} < 1\}$ and $J_h(b) = \{\rho \in P \mid \rho > \rho_l = \frac{\mu F_l - B*}{\mu F_l - b} < 1\}$. Once again, $J_h(b) \subset J_l(b)$ implying that type l is more likely to have deviated. This is not consistent with the out-of-equilibrium beliefs required to sustain the pooling equilibrium. Similar arguments can be applied to other pooling equilibria.

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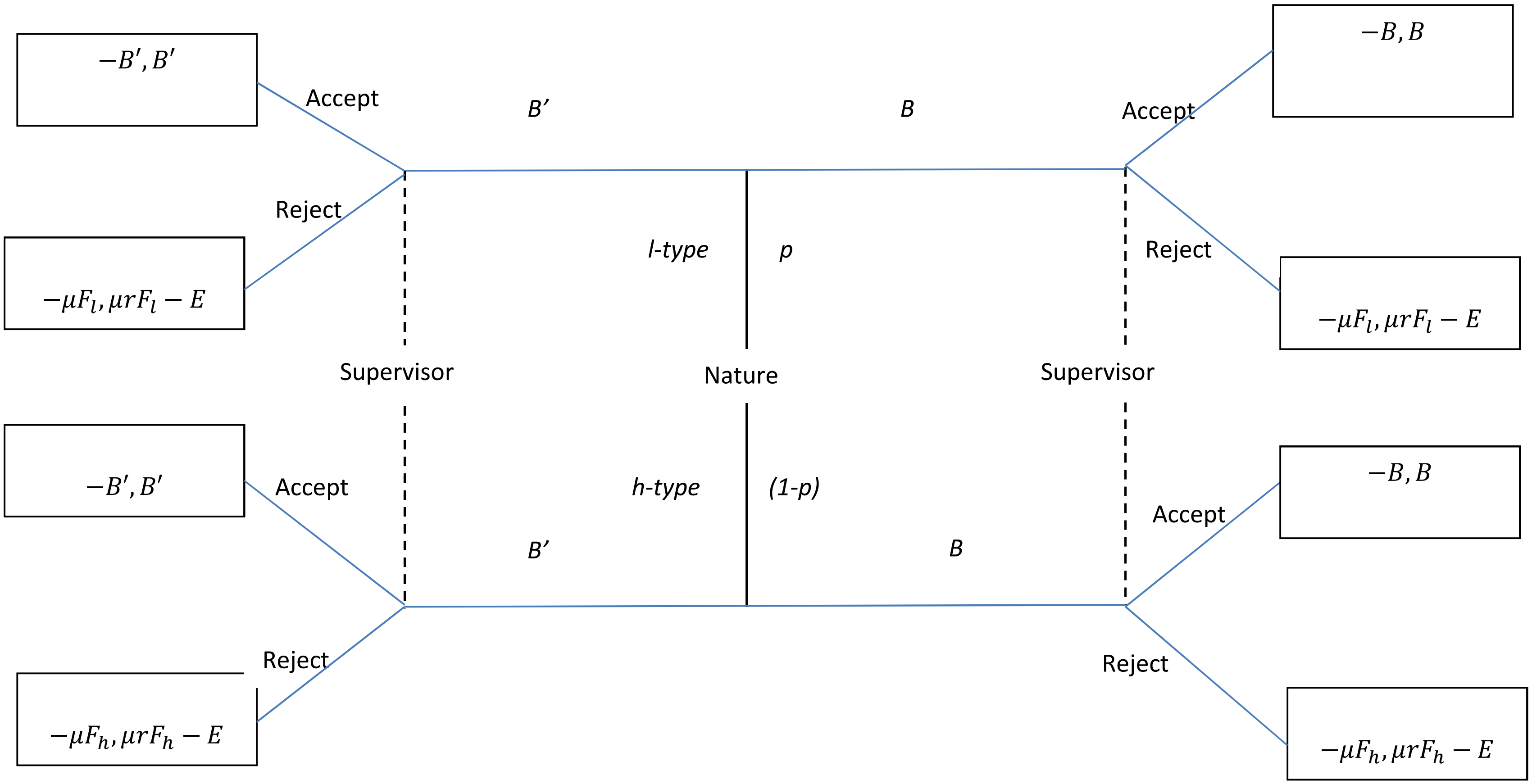

$-B', B'$
Accept
B'
B
Accept
$-B, B$
Reject
$-\mu F_l, \mu r F_l - E$
l-type
p
Reject
$-\mu F_l, \mu r F_l - E$
Supervisor
Nature
Supervisor
$-B', B'$
Accept
h-type
(1-p)
$-B, B$
Accept
B'
B
Reject
$-\mu F_h, \mu r F_h - E$
Reject
$-\mu F_h, \mu r F_h - E$

Figure 1